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Analysis of heavy metal concentration and its bioaccumulation in Gerres filamentosus (Cuvier, 1829) from Ashtamudi Lake, Kollam, Kerala, South India

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Abstract

This study investigates the distribution of heavy metals in Ashtamudi Lake, a significant freshwater ecosystem in South India, and its implications for the health of *Gerres filamentosus*, a commercially important fish species. Samples were collected from two sites within the lake, and concentrations of Zinc (Zn), Iron (Fe), and Lead (Pb) were measured in water, sediment, and fish tissues. The results were compared to World Health Organization (WHO) guidelines to assess potential risks to human health. The study found that Fe was the most abundant heavy metal in all samples, followed by Zn and Pb. Gill tissues of the fish species had the highest metal accumulation, while muscle tissues had the lowest. While, at site 2, out of the three heavy metals, the concentration of Fe in the muscle tissues exceeded the limit recommended by the WHO. Consequently, prolonged consumption of fish from this region could potentially lead to health risks associated with Fe toxicity. Overall, the findings suggest that Ashtamudi Lake, particularly the second site, is polluted with heavy metals, posing potential risks to both aquatic organisms and human health. The study underscores the importance of environmental protection measures to preserve the health and integrity of this vital ecosystem.

Key words: Ashtamudi Lake, Ecosystem, Gerres filamentosus, Heavy Metals

Introduction

Aquatic ecosystems are vital for human survival and the health of the planet. They provide essential services such as water purification, nutrient cycling, and habitat for diverse flora and fauna. However, these ecosystems are increasingly threatened by pollution, including heavy metals, which can have severe consequences for both aquatic life and human health.

Heavy metals are naturally occurring elements that can become concentrated in aquatic environments due to human activities such as mining, industrial processes, and urbanization. These metals, including Zn, Fe, and Pb, can enter water bodies through various pathways, such as atmospheric deposition, runoff from agricultural and urban areas, and direct discharge from industrial facilities (Karim, L. R., & Williams, E. S. (2015). Once in the water, heavy metals can accumulate in sediments and biota, including fish, which can lead to bioaccumulation and biomagnification in the food chain. This accumulation can have adverse effects on aquatic organisms, such as impaired growth, reproduction, and immune function. Moreover, heavy metals can also pose risks to human health through the consumption of contaminated fish and water.

Ashtamudi Lake, located in the southern Indian state of Kerala, is one such aquatic ecosystem facing the threat of heavy metal pollution. This lake is the second-largest in Kerala and is known for its rich biodiversity, including a variety of fish species. However, rapid urbanization and industrialization in the region have led to increased pollution levels in the lake, including heavy metals. Therefore, this study aims to assess the distribution of heavy metals in Ashtamudi Lake, focusing on the concentrations of Zn, Fe, and Pb in water, sediment, and tissues of Gerres filamentosus. The study also aims to evaluate the potential health risks posed by heavy metal contamination to both aquatic organisms and human consumers. By understanding the extent of heavy metal pollution in Ashtamudi Lake and its impact on Gerres filamentosus, this research seeks to provide valuable insights into the conservation and management of this vital aquatic ecosystem.

Materials and Methods

Study Area and Sampling Sites

The study was conducted in Ashtamudi Lake, a significant freshwater ecosystem located in the southern Indian state of Kerala. Ashtamudi Lake is the second-largest lake in Kerala and is known for its rich biodiversity, including a variety of fish species. Two sampling sites were selected within Ashtamudi Lake (Figure 1) to represent different levels of anthropogenic activity and potential heavy metal pollution.

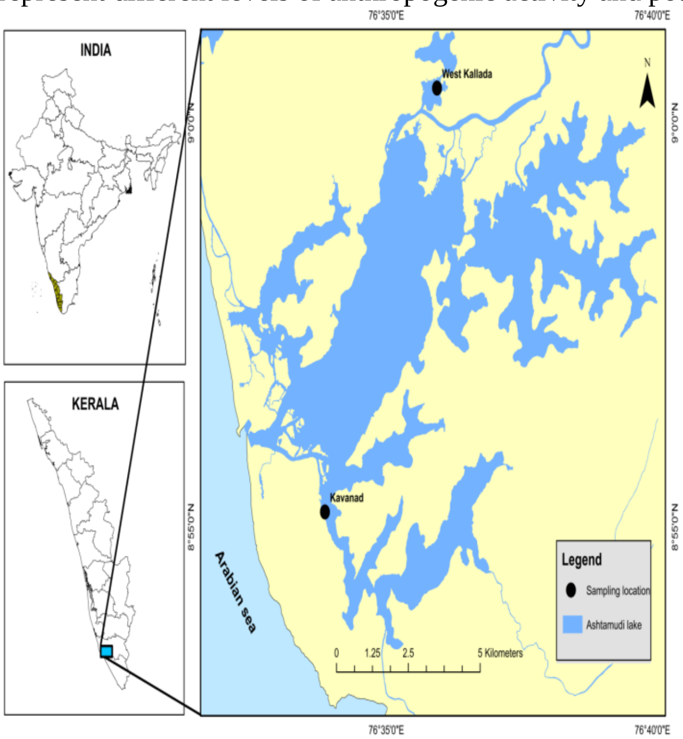

Figure 1. Location map of Ashtamudi Lake

Site 1: West Kallada

West Kallada is situated along the Kallada River, which originates from the Western Ghats and flows westward, eventually draining into Ashtamudi Lake. The site is approximately 3 km north of the Kallada River's confluence with Ashtamudi Lake. West Kallada was chosen as the reference site (Site 1) due to its relatively remote location and minimal human interference, making it less polluted compared to other areas of the lake (Figure 2).

Figure 2. West Kallada

Site 2: Kavanadu

Kavanadu is a narrow strip of land located between the Arabian Sea and Ashtamudi Lake, approximately 3 km from the Neendakara fishing harbor. This area is characterized by high levels of anthropogenic activity, including the use of mechanized fishing boats and oil spillage from the harbor. Additionally, the presence of welding and electroplating workshops, as well as organic waste from domestic and fish processing units, contribute to significant pollution in this region. Kavanadu was selected as Site 2 to represent a highly polluted area within Ashtamudi Lake (Figure 3).

Figure 3. Kavanadu

Sampling at each site was conducted during the dry season to minimize the influence of rainfall and runoff on heavy metal concentrations. Water, sediment, and fish samples were collected from both sites for analysis. Water samples were collected using a Van Dorn water sampler at a depth of 1 meter. Sediment samples were collected using a grab sampler from the lake bottom. Fish samples of *Gerres filamentosus* were captured using gill nets and hand nets.

Candidate species: Whipfin silver biddy

Fig 4. *Gerres filamentosus* (Cuvier, 1829)

Table 1. Scientific classification

Kingdom	**Animalia**
Phylum	Chordata
Class	Teleostomi
Sub-class	Actinopterygii
Order	Perciforms
Family	Gerreidae
Genus	*Gerres*
Species	*filamentosus*

Analysis of Heavy Metals in Water

The concentration levels of heavy metals in water samples were analyzed using a Microwave Plasma Atomic Emission Spectrometer (Model: Agilent 4210). This instrument allows for the precise measurement of heavy metal concentrations in water samples.

Analysis of Heavy Metals in Sediments

Sediment samples were first dried in a hot oven for 24 hours and then ground into a fine powder using a motor and pestle. Approximately 0.25g of this fine sediment powder was accurately weighed and placed in a dry and clean Teflon crucible. A mixture of Supra Pure Nitric Acid (HNO3) and Perchloric Acid (HCLO4) in the ratio 5:1 was added to the crucible, and the sample was digested at a temperature of ≤ 50°C by placing the beaker on a hot plate. The digested samples were then diluted with 25 ml of distilled water and filtered into a 100 ml standard measuring flask. The digested samples were subjected to heavy metal analysis using a Microwave Plasma Atomic Emission Spectrometer (MP-AES, Model: 4210) instrument.

Analysis of Heavy Metals in Tissues

For heavy metal analysis, boneless organs such as gill, liver, and muscles were taken. These organs were removed using stainless-steel instruments. Digestion of fish tissues was carried out by taking 2 grams of each fresh tissue and drying the samples in a hot oven for 24 hours. After the desired time, the samples were removed from the oven and crushed into a fine powder using a motor and pestle. The powdered sample was then digested with hydrogen peroxide (> 35% H2O2) and nitric acid (65% HNO3) in a glass beaker. The beaker was placed on a hotplate under the fume hood until the yellow fumes were replaced by white and then set to cool at room temperature. The sample was then made up to 100 ml with metal-free double distilled water and filtered using Whatman filter paper. The filtrate was analyzed for heavy metals such as Pb, Fe, and Zn concentrations according to APHA (1998) on the Microwave Plasma Atomic Emission Spectrometer (MP-AES, Model: 4210) instrument.

Statistical Analysis

The linear relationship of data obtained for heavy metals in water, sediment, and tissues was statistically analyzed using the Pearson correlation coefficient. All statistics were performed using SPSS (version 25) statistical program. The data were plotted on tables and graphs using Microsoft Word (2013) for convenient visualization.

Results and discussion

Water Sample Analysis

The analysis of water samples from the study sites revealed concentrations of zinc (Zn), iron (Fe), and lead (Pb) within permissible limits set by the World Health Organization (WHO) at both site 1 and site 2 (Table 2). Specifically, Zn levels were below the WHO limit of 5.00 ppm, with concentrations at site 1 being below detection limits (BDL) and at site 2 at 0.01 ppm. Fe concentrations were also below the WHO limit of 5.00 ppm, with levels at site 1 (BDL) and site 2 (0.05 ppm). Pb concentrations were below the WHO limit of 0.1 ppm at both sites, with levels at site 1 (BDL) and site 2 (BDL). These findings suggest that the water quality at the study sites meets international standards for heavy metal concentrations, indicating minimal risk to human health and aquatic ecosystems. Similar results were reported by Olayinka-Olagunju*et al*., (2021) and Hassan et al., (2015).

Table 2. Comparing the heavy metal analysis in the water and sediment samples with WHO standards (1989)

Heavy metals	WHO limits	Water (ppm)		WHO limits	Sediment (ppm)	
		Site 1	Site 2		Site 1	Site 2
Zinc	5	BDL	0.01	≤ 1	BDL	34.91
Iron	5	BDL	0.05	5	BDL	78.53
Lead	0.1	BDL	BDL	5	3.22	8.3

The observed reduction in heavy metal concentrations in water samples may be attributed to various factors, including the dilution effect of heavy rainfall (Olayinka-Olagunju et al., 2021)., adsorption, and accumulation of heavy metals by suspended solid materials (Ayas et al., 2007). Heavy rainfall events can lead to increased river flow, resulting in the dilution of contaminants in water bodies (Mohiuddin et al., 2012; Islam et al.,2015a). Additionally, suspended solid materials in water can adsorb and accumulate heavy metals, reducing their concentration below detection limits. These natural processes play a crucial role in regulating heavy metal levels in aquatic environments, contributing to overall water quality.

Sediment Analysis

Analysis of sediment at site 1 indicated that the concentrations of Zn, Fe and Pb were within the permissible limits by the WHO. While at site 2 sediment analysis revealed that the elevated levels of heavy metals than water samples, indicating potential pollution hotspots. The concentrations of Zn, Fe and Pb in sediment samples exceeded WHO limits, at site 2 the concentration was in the order of Zn (34.91 ppm) > Fe (78.53 ppm) and Pb > (8.30 ppm) compared to WHO concentration limit (5.00 ppm). These findings highlight the importance of sediment analysis in assessing the long-term accumulation and persistence of heavy metals in aquatic environments. Sediments act as sinks and carriers for pollutants, accumulating heavy metals over time and serving as potential sources of contamination to water bodies (Benson and Etesin, 2008). The higher concentrations of heavy metals in sediments compared to water samples underscore the importance of monitoring sediment quality to assess the health of aquatic ecosystems (Khan et al., (2008). The observed variation in heavy metal concentrations between study sites suggests differences in contamination sources and environmental factors influencing metal deposition and accumulation Bazrafshan et al., (2015). Effective management strategies are needed to mitigate sediment pollution and protect aquatic ecosystems from the adverse effects of heavy metal contamination (Simpson et al., 2004; Li et al., 2013).

Fish Tissue Analysis

Analysis of heavy metal concentrations in fish tissues (Table 3) provided further insights into the bioaccumulation and biomagnification of contaminants in aquatic food chains. *Gerres filamentosus*, a commonly consumed fish species in the study area, was selected for tissue analysis. The concentrations of Zn, Fe, and Pb in fish tissues varied between sites, with site 2 showing higher levels of contamination compared to site 1.

Table 3. Comparing the heavy metal analysis in the tissue samples of *Gerres filamentosus*.

Heavy metals		Site 1			Site 2		
	WHO limits (ppm	Gill	Liver	Muscle	Gill	Liver	Muscle
Zn	40	33.14	35.39	12.29	50.4	46.79	20.43
Fe	100	54.63	60.71	39.84	1739.32	640.05	260.76
Pb	0.5	BDL	BDL	BDL	0.16	0.03	BDL

At site 2, concentrations of Zn and Fe in fish gills and liver tissues exceeded WHO limits, indicating potential health risks associated with heavy metal exposure (Yehia and Sebaee, 2012). The accumulation of heavy metals in fish tissues can pose significant threats to human health through the consumption of contaminated fish

(Olgunoglu*et al.*, (2015). Additionally, the biomagnification of contaminants in aquatic food chains can lead to higher concentrations of heavy metals in higher trophic levels, further exacerbating human exposure risks (Yousafzai et al., 2017). The findings of this study highlight the importance of monitoring heavy metal concentrations in fish tissues to assess the safety of aquatic food sources and protect public health. Sustainable fisheries management practices and pollution control measures are essential for minimizing heavy metal contamination in fish populations and ensuring the sustainability of aquatic ecosystems (Figure 5, 6 & 7).

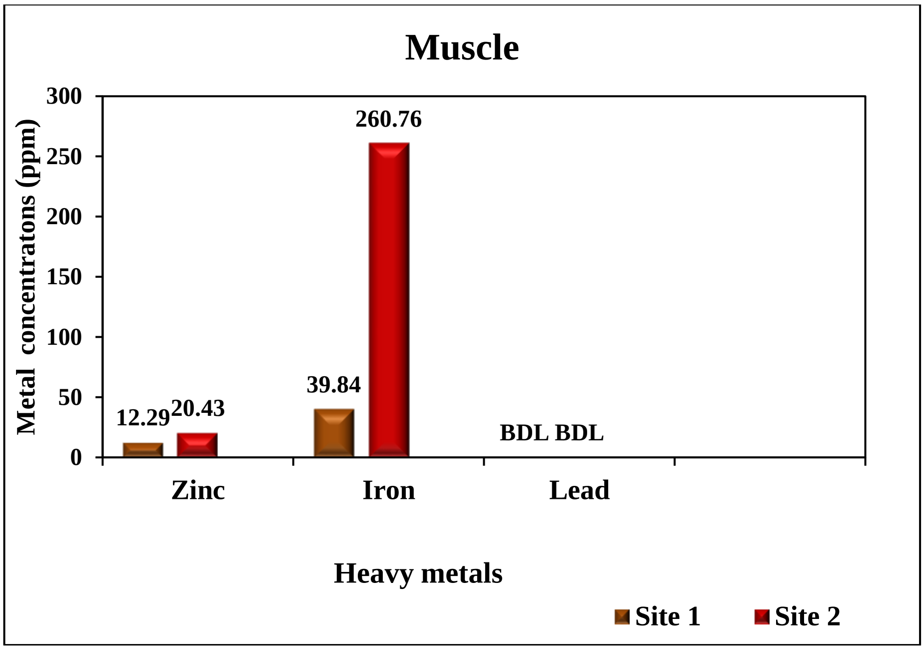

Figure 5. Site 1 & 2 concentrations of Zn, Fe and Pb in fish Muscles

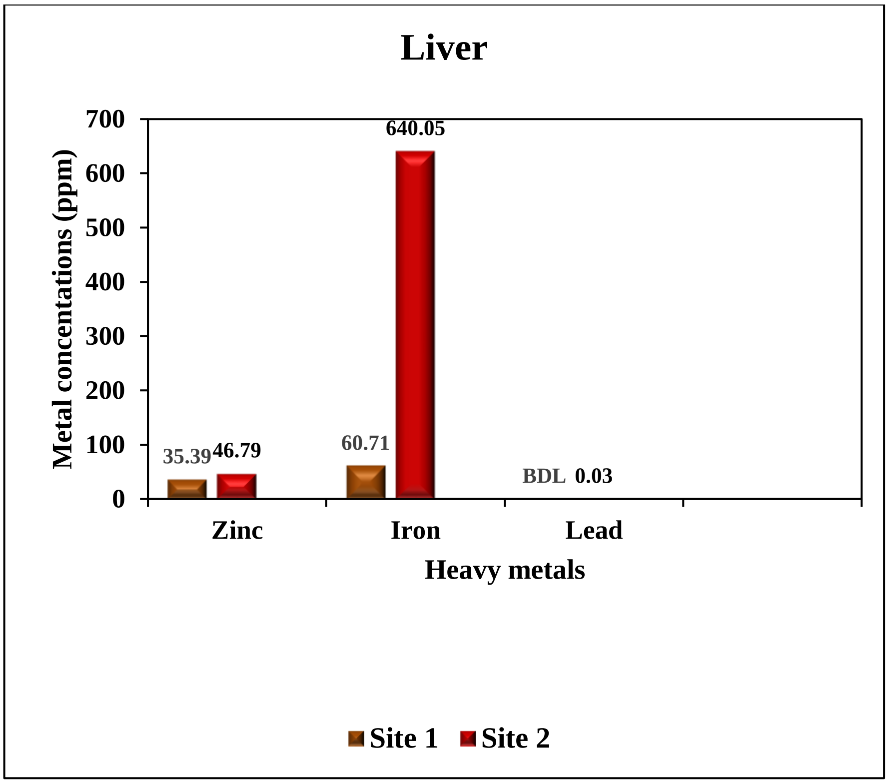

Figure 6. Site 1 & 2 concentrations of Zn, Fe and Pb in fish Liver

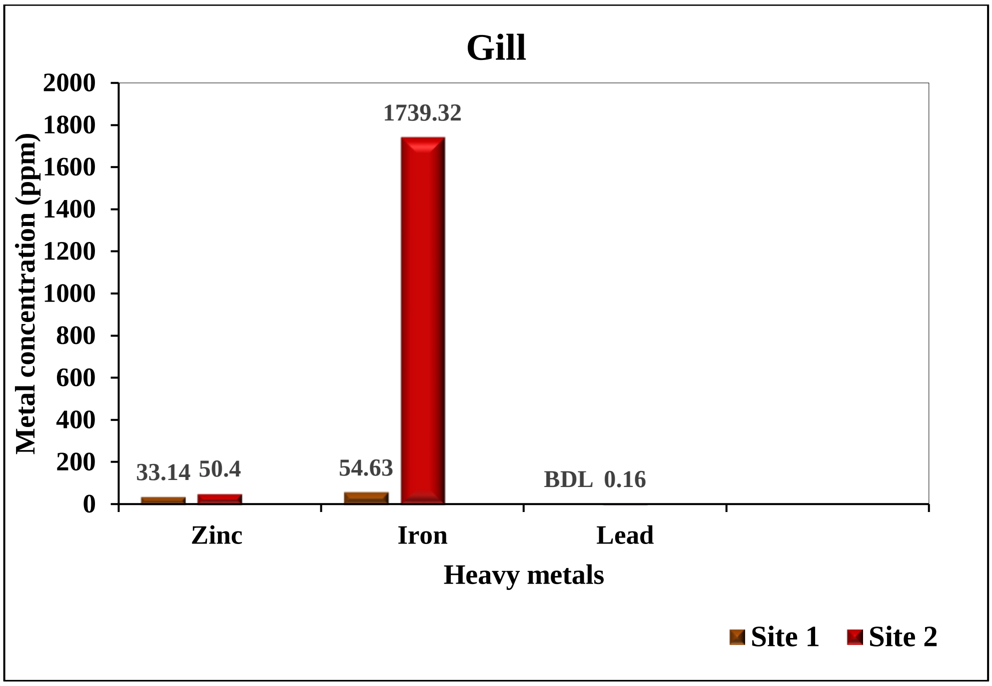

Figure 7. Site 1 & 2 concentrations of Zn, Fe and Pb in fish Gills

CORRELATION ANALYSIS

Correlation between water and sediment

Pearson correlation coefficient was used to test the correlation between water and sediment in site 2. From the Pearson correlation coefficient, Table 3 showed that there was no significant correlation between water and sediment since the P-value is greater than 0.05 (Table 4, 5 & 6).

4.4.2. Correlation between water and tissue

From the Pearson correlation coefficient, Table 4 showed that the P-value is less than 0.05 for all the tissues examined in site 2. Therefore, the present study concludes that there is a significant correlation between water and each tissue of *G.filamentosus*.

4.4.3. Correlation between sediment and tissue

From the Pearson correlation coefficient, Table 5 showed that the P-value is greater than 0.05 for all the tissues in site 2. Therefore, the present conclude that there is no significant correlation between sediment and each tissue of *G. filamentosus.*

Table.4 Correlation analysis of heavy metals between water and sediment

		Water	Sediment
Water	Pearson Correlation	1	.927
	Sig. (2-tailed)		.245
	N	3	3
Sediment	Pearson Correlation	.927	1
	Sig. (2-tailed)	.245	
	N	3	3

Table. 5 Correlation analysis of heavy metals between water and tissue

Correlation				
		Gill	Liver	Muscle
water	Pearson Correlation	1.000*	.998*	.998*
	Sig. (2-tailed)	.016	.042	.045
	N	3	3	3
*. Correlation is significant at the 0.05 level (2-tailed).				

Table. 6 Correlation analysis of heavy metals between sediment and tissue

Correlation				
		Gill	Liver	Muscle
Sediment	Pearson Correlation	.936	.950	.951
	Sig. (2-tailed)	.229	.203	.200
	N	3	3	3
*. Correlation is significant at the 0.05 level (2-tailed).				

The results of the correlation analysis showed that there is a significant difference in the accumulation pattern of heavy metals in water, sediment, and tissues of G. filamentosus. The present findings are in agreement with the study conducted by Demirak et al., (2006) observed that there is no correlation was found between the concentration level of heavy metals in water and sediment. A study done by Mao et al., (2020) revealed that when theheavy metal concentrations in water increased and there is no significant variations in the concentration level of heavy metals in sediment. Shanbehzadeh et al., (2014) carried out a correlation analysis to determine the relationship between the heavy metal concentration in water and sediment and observed that during the rainy season there is a transfer of heavy metal ions from water to sediment. A notable linear relationship marked between the heavy metal concentrations in fish tissues with that of water was reported by Pandey et al., (2020). Aquatic life forms such as fish were able to bio-accumulate heavy metals in their living cells to a concentration level that is higher than those in water andsediment (Forstner and Wittmann, 1981). Bioaccumulation patterns of heavy metals in water, sediment, and fish fishes vary according to environmental conditions as well as biological factors (Blackmore and Wang, 2003; Jezierska and Witeska, 2006).

Conclusion

In conclusion, this study provides valuable insights into the distribution, concentration, and sources of heavy metals in aquatic environments. Water sample analysis revealed compliance with WHO standards for heavy metal concentrations, indicating satisfactory water quality at the study sites. However, sediment analysis identified potential pollution hotspots, particularly at site 2, where elevated levels of heavy metals were detected. At site 2, the concentration of Fe in the muscle tissue exceeded the permissible limit recommended by the WHO. Consequently, prolonged consumption of fish from this region could potentially lead to health risks associated with iron toxicity. Fish tissue analysis further demonstrated the bioaccumulation of contaminants, highlighting potential health risks associated with heavy metal exposure through the consumption of contaminated fish.

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